ROAD RECLAMATION: MEASURING SUCCESS

Debris flows like the one above, and cut or fill slope failures (as shown below) are just a few of the problems often encountered on the Forest Service's road system.

Photos courtesy of USDA Forest Service.

From its earliest days, the Forest Service has been building and managing forest roads to provide access for recreation and resource management. Once thought of as assets, the agency and the public now understand that an oversized road system is also a liability, both fiscally and ecologically. Recognizing that, Congress created the Legacy Roads and Trails Remediation Program (LRT) in 2008, funneling $270 million to that program over the past five years. And while the Forest Service has documented the work accomplished with this funding, they have only just begun to measure what it means on the ground. This report summarizes new research from the Rocky Mountain Research Station regarding LRT's impacts on stream sedimentation and hydrologic problems. It also discusses how this research protocol can be used to help prioritize road-based watershed restoration spending in the future.

As likely the largest road management entity in the world, the Forest Service is responsible for 375,000 miles of system roads plus an additional 60,000 miles or more of nonsystem roads across its 193 million acre landscape. In addition to the significant expense of maintaining such a large road system, these roads cause profound impacts to natural resources, including streams, such as:

- Sediment runoff from roads and trails ends up in streams and rivers, smothering fish eggs and inhibiting nest building;
- Compacted road beds alter hydrology by impeding water infiltration and blocking subsurface water flow;
- Roads constructed on highly erodible soils are prone to severe landslides. Sediment released from landslides have interrupted and degraded the drinking water supplies of numerous communities;
- Chronic sediment can degrade municipal water supplies, potentially causing municipalities to install or upgrade filtration systems;
- Blocked, undersized or improperly installed culverts can prevent fish and other organisms from accessing important habitat, including spawning areas.

LRT was designed to help address these impacts to clean water and fisheries. To date, Congress has sent $270 million to the program, and they've achieved extraordinary success. As a result of the first $225 million the agency received (FY08-FY11), the Forest Service has:

- Improved or maintained 10,478 miles of road;
- Decommissioned 4,284 miles of road;
- Restored fish passage at 1,224 culverts;
- Improved 298 bridges;
- Maintained or improved 2,334 miles of trail.

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But what do these road and trail based accomplishments mean when it comes to sediment in the streams? Does decommissioning or "stormproofing" actually work to address the impacts listed above? The Forest Service wondered the same thing, so researchers developed tools and a process for analyzing the effects of roads in forests: The Geomorphic Roads Analysis and Inventory Package (GRAIP).

GRAIP is being used in two types of case studies. The first assesses how effective the Legacy Roads and Trails program really is at correcting sedimentation and hydrologic problems. The second is an intensive watershed analysis of road impacts. All of the GRAIP research to date is based on actual field-data collected in every project area, along with some modeling estimates for baseline sedimentation rates. For the Legacy Roads and Trails studies, this entails collecting hundreds of data points. For the watershed analyses, tens of thousands of data points have been collected, with field crews literally walking every inch of road.

Technicians conducting a stream crossing pebble count as part of a post-decommissioning inventory.

The result of all this data collection? Legacy Roads and Trails is working! Road decommissioning is returning the land to near normal conditions, dramatically reducing the amounts of dirt entering streams. Stormproofing appears to be slightly less beneficial than road decommissioning, but that may change as more post-storm analyses are completed. Finally, the watershed analysis case studies have resulted in fascinatingly consistent data showing that a very small percentage of forest road mileage is causing a very large percentage of stream sedimentation.

Installing a rain gauge on the Siuslaw National Forest. Photo courtesy of USDA Forest Service.

Legacy Roads and Trails Study Results

The GRAIP tools and process were applied to 47 Legacy Roads and Trails projects across the Pacific and Intermountain West to assess the effectiveness of two LRT activities: road decommissioning and road "storm damage risk reduction" (often referred to as 'stormproofing' (SDRR). Specifically, GRAIP assessed the effectiveness of treatments in reducing:

- road-stream hydrologic connectivity;
- fine sediment production and delivery;
- mass wasting;
- shallow landslide risk;
- gully initiation risk;
- drain point condition;
- stream crossing failure risk (Nelson et al. 2011, Luce 2011).

Ideally, data is collected both pre- and post- storm to test how effective the treatments were. For a full explanation of the methodology, view the GRAIP website (http://www.fs.fed.us/GRAIP/index.shtml).

While the Forest Service has collected data for 47 Legacy Roads and Trails sites, as of this review, they have compiled data on just over half (11 decommissioning and 12 stormproofing sites). Nine of the decommissioning sites have also had post-storm surveys, compared to only four stormproofing sites (storms are unpredictable and must be of a certain magnitude to qualify for the study).

Decommissioning treatments included both full and partial recontouring of the road prism and intensive restoration of stream crossings. Stormproofing utilized lower cost treatments that were applied extensively across the road system to increase drainage frequency and capacity, improve road surfaces and reduce the risk of stream crossing failure (Luce, C. 2011). The results of the two types of treatments are summarized in the tables on the following page.

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Cumulative Effects of LRT Treatments Following Project Completion

Initial Treatment Effects		
	Decommissioned Roads n=11 segments, 67.7 km	**SDRR Roads n=12 segments, 86.3 km**
Road-Stream Hydrologic Connectivity	**-9.8 km**, reduced from 16.9 to 7.1 km (**-58%**)	**-2.3 km**, reduced from 24.9 to 22.6 km (**-9%**)
Fine Sediment Delivery	**-119 Mg/yr**, reduced from 187 to 67 Mg/yr (**-64%**)	**-119 Mg/yr**, reduced from 235 to 116 Mg/yr (**-51%**)
Drainpoint Problem Rate	Reduced from 22% to 3% (**-86%**)	Reduced from 25% to 14% (**-48%**)
Unit Sediment Delivery	**-1.8 Mg/yr/km**, reduced from 2.8 to 1.0 Mg/yr/km (**-64%**)	**-1.4 Mg/yr/km**, reduced from 2.7 to 1.3 Mg/yr/km (**-51%**)

From Black, et al. 2012a. One Mg/yr is one metric ton of sediment delivered to a stream each year.

The Forest Service is using the GRAIP methodology to measure the effectiveness of various restoration treatments to roads.

Photos courtesy of USDA Forest Service.

Picture a 1-ton pick-up truck and the size of its bed, then picture that filled with dirt and dumping that dirt into a stream. Perhaps that helps illustrate how much sediment is really going into these streams. In the chart above, the study shows that 119 less truckloads of sediment are entering streams. The chart below shows that post-storm, nearly 200 truckloads of sediment did NOT enter the stream. And remember, this is just on 11 sites - approximately 42 miles of decommissioned roads.

Cumulative Results of LRT Post-Storm Validations

Post-Storm Validation				
	Decommissioned Roads, n=9		**SDRR Roads, n=4**	
	Treated, 60.5 km	**Control, 58.2 km**	**Treated, 26.4 km**	**Control, 25.0 km**
Road-Stream Hydrologic Connectivity	**-6.9 km,** reduced from 15.8 to 8.9 km (**-44%**)	**+4.2 km**, increased from 12.9 to 17.0 km (**+33%**)	**+1.1 km**, increased from 9.8 to 10.9 km (**+11%**)	**+0.2 km**, Increased from 7.5 km to 7.7 km (**+3%**)
Fine Sediment Delivery	**-194 Mg/yr**, reduced from 244 to 50 Mg/yr (**-80%**)	**+89 Mg/yr**, increased from 105 to 204 Mg/yr (**+94%**)	**-80Mg/yr**, reduced from 119 to 39 Mg/yr (**-67%**)	**No Change**, from 28 to 28 Mg/yr (**0%**)
Drainpoint Problem Rate	Reduced from 21% to 13% (**-38%**)	Increased from 16% to 24% (**+50%**)	Reduced from 24% to 15% (**-38%**)	**-1%**, decreased from 25% to 24% (**-4%**)
Unit Sediment Delivery	**-3.3 Mg/yr/km**, reduced from 4.1 to 0.8 Mg/yr/km (**-80%**)	**+1.7 Mg/yr/km**, increased from 1.8 to 3.5 Mg/yr/km (**+94%**)	**-3.0 Mg/yr/km**, reduced from 4.5 to 1.5 Mg/yr/km (**-67%**)	**No Change**, 1.3 Mg/yr/km (**0%**)

From Black, et al. 2012a. One Mg/yr is one metric ton of sediment delivered to a stream each year.

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Implications of LRT

The results illustrate the great promise of the Legacy Roads and Trails program. The GRAIP study clearly shows that decommissioning significantly reduces the impacts of the road system on streams, drastically reducing sedimentation and restoring hydrologic function. Stormproofing is also beneficial, but does not necessarily provide as much return on investment. This study shows that Legacy Roads and Trails projects result in significantly cleaner water, which:

- Improves municipal water supplies, bringing economic and ecological advantage to both water suppliers and their customers;
- Increases survival and enhances habitat quality for threatened/endangered fish; and
- Improves recreational opportunities –fishing, swimming, and boating.

Concerned with budget deficits, Congress continues to cut LRT and, unfortunately, its accomplishments. In addition, the program may be jeopardized with getting lost within the new "Integrated Resource Restoration" approach. Rather than suffering either of these fates, however, ***Congress should increase investment and highlight Legacy Roads and Trails as an exemplary model of watershed restoration that works!***

Watershed Analysis Study Results

Researchers have also been using GRAIP on a second type of case study to better understand what part of the road network is the greatest contributor to stream sedimentation. To do so, they conducted very intensive analyses in multiple watersheds in Oregon and Idaho. The purpose of these is to determine where the highest risk areas are and to target treatments there. GRAIP is used to produce maps of landslide and gully initiation risk and to predict:

- road surface erosion;
- sediment delivery;
- hydrologic connectivity; and,
- stream crossing failure and diversion risk (Flanagan et al, 1998).

The results are astounding, with consistent conclusions that a small percentage of forest road mileage is causing a very large percentage of stream sedimentation. While the data varies slightly from watershed to watershed, cumulatively, (as seen in the graph on the following page) approximately 7% of drain points (solid yellow vertical line) are delivering 90% of the sediment (dashed green horizontal line) to nearby streams. This is an extraordinary result, with significant management implications.

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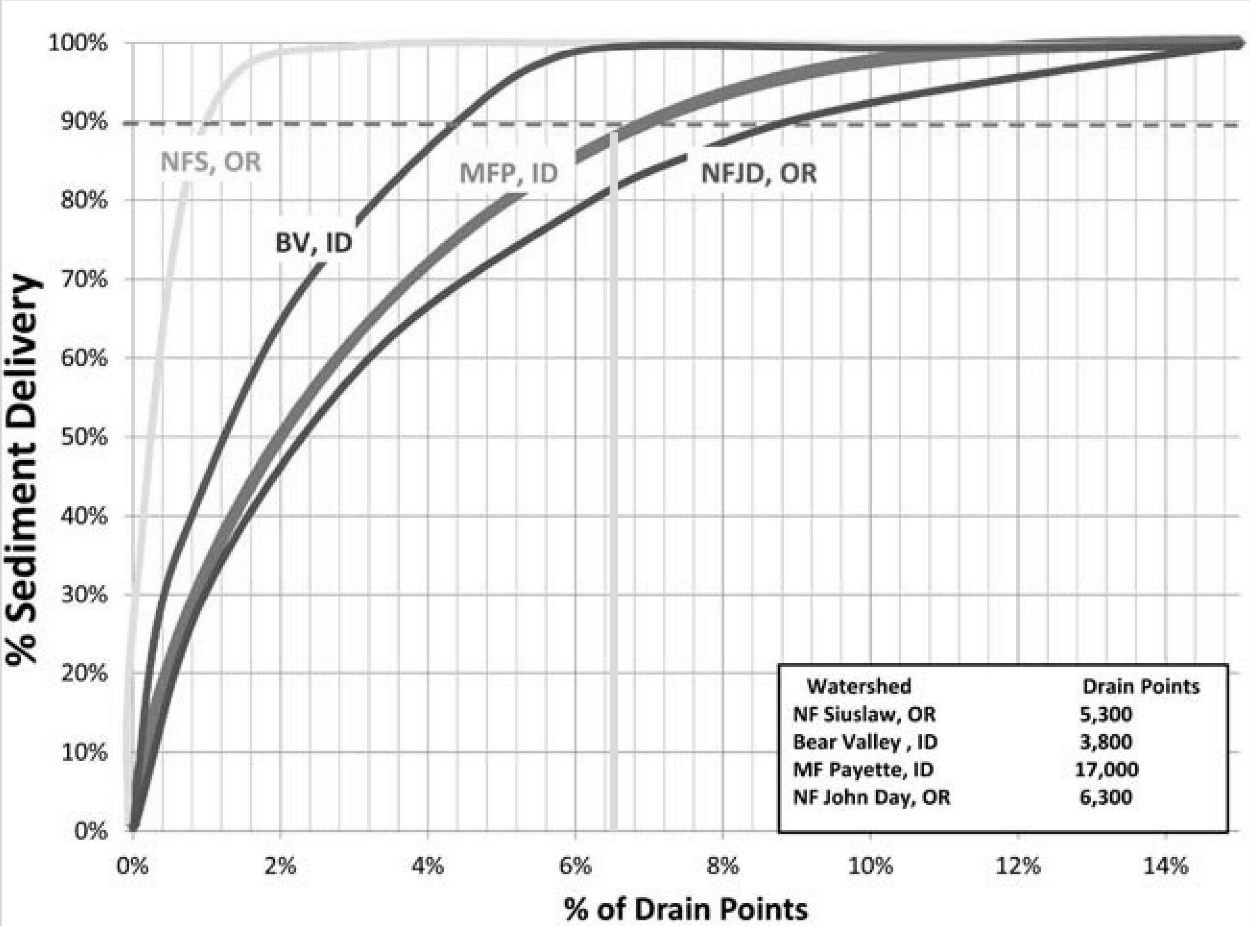
Looking ahead, the Legacy Roads & Trails Program has great potential to reduce the overall impacts of the road system on water quality. Above, a recontoured road on the Olympic NF.

Below, a post-stormproofing broad based dip over a stream crossing.

Photos courtesy of USDA Forest Service.



From T. Black, Legacy Roads Monitoring Project Update 2012

Implications of Watershed Analysis Research

These watershed analyses can provide extraordinarily valuable information regarding where funding should be directed to address road-caused sedimentation. For example, data collected has been used to create watershed restoration plans for all or parts of the four watersheds in the chart above. Importantly, data such as this can be a critical component of the agency's ongoing effort to identify an ecologically and fiscally sustainable road system. With this data in hand, managers can:

- assess which roads cause the most hydrologic harm and stream sedimentation;
- mitigate the problem sites on roads that remain critical for access;
- restore watershed function and connectivity by reclaiming those roads deemed unnecessary for access/resource management needs.

Data from the GRAIP analyses shows which types of practices *produce* the most sediment, as compared with which type of practices *deliver* the most sediment to streams. So, for example, while ditch relief culverts produce only 18% of the sediment produced by roads, they are responsible for 34% of the sediment that ends up in the stream system. Similarly, stream crossings only produce 3% of the sediment, but are responsible for 17% of that which enters streams. This type of information will help the agency improve road management practices.

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GRAIP
Improved Efficiency

$1,200,000 Restoration Project

Cost = Unit Cost * % Treated * Total Road Mileage

GRAIP	Non-GRAIP
Survey: $135,000	Survey: $0
Treatment: $1,065,000	Treatment: $1,200,000
Miles Treated: 43	Miles Treated: 48
% Treated: 7.3%	% Treated: 8.2%
Sediment Reduced: **71%**	Sediment Reduced: **29%**

The chart above (from Black et al. 2012b) shows how GRAIP can be used to profoundly increase effectiveness of the Watershed Condition Framework, Legacy Roads and Trails, and/or other road management efforts. Though nearly the same percentage of the road system will be treated, the project using a GRAIP survey (Scriver Creek, Boise National Forest) will reduce stream sedimentation by a far greater percentage than a theoretical project using standard methodologies.

This Siuslaw National Forest road has been decommissioned. Photo courtesy of USDA Forest Service.

The GRAIP protocols are equally important for the ongoing Watershed Condition Framework (WCF) process and Integrated Resource Restoration, and can be used at nearly every stage of the WCF, from assessment, to priority-setting, to pre- and post-treatment monitoring. With limited dollars, it makes sense to ensure that every road decommissioning or road maintenance dollar is being spent wisely. GRAIP helps make that possible (see "GRAIP Improved Efficiency" at left).

Similarly, GRAIP can help identify where road-caused sedimentation is being delivered into municipal water supplies and to direct public or private funding to address those roads. The agency is testing computer modeling approaches built on the GRAIP protocol — this would enable them to extend this type of research to far more watersheds, but it is complex. Finally, the GRAIP results from the Legacy Roads and Trails case studies make clear that the most effective road treatment, where conditions permit, will be decommissioning — this is an important lesson to apply to the watershed analyses.

What's Next?

The results from both of these GRAIP case study analyses are exciting and provide opportunities to significantly improve road management and watershed restoration planning. The Forest Service has never had a better tool for prioritizing needed road work based on hydrology and sedimentation. This is one of the major issues the agency is assessing as part of the effort to identify a sustainable road system. It is also, as mentioned above, a key component of the Watershed Condition Framework and Integrated Resource Restoration. Finally, such data can play an important role in revised forest planning.

The timing is more important than ever, as recent Forest Service studies show the importance of national forest lands for providing clean drinking water to the American public. According to the agency, nearly 1 in 5 Americans relies on national forests for their municipal water supplies. With roads responsible for so much sedimentation of streams, GRAIP provides a tool to tackle this problem head on and ensure high quality water supplies long into the future. For example, GRAIP can be used to measure the effectiveness of road-related Best Management Practices for sedimentation.

As we move forward, however, we must recognize that the GRAIP results have important limitations. The analyses relate exclusively to roads and sedimentation/hydrology impacts. Therefore GRAIP cannot be considered a surrogate for all road mitigation needs, though it does allow the agency to address at least one category of impacts in a highly effective manner. GRAIP does not address any other types of road impacts, of which there are many. These include fish passage or other forms of aquatic connectivity; terrestrial connectivity; road-related weed impacts, and the importance of roadless areas as refugia for wildlife and wild nature. Ideally the agency will develop equally robust tools to assess some of these other problems and to derive equally relevant recommendations regarding road management on roads that aren't causing significant stream sedimentation. The complex process the agency is using to determine which roads to reclaim and which to keep must assess all of these impacts.

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GRAIP CASE STUDY

MONITORING THE EFFECTIVENESS OF ROAD DECOMMISSIONING

Mann Creek, Payette National Forest

Mann Creek, on Idaho's Payette NF, is one of the first places where Forest Service researchers were able to conduct post-storm monitoring on a decommissioned road and publish the results. Researchers have studied nearly a dozen other sites with post-storm validation, but are still consolidating data on most of those.

Here's a brief excerpt from their report. "Treatments were expected to reduce annual sediment production by 56% and annual sediment delivery by 98%. Post-storm surveys indicate these reductions may be closer to 73% for sediment production and 99% for delivery. Recontouring the road surface eliminated the longitudinal, concentrated flowpath and replaced it with a transverse, diffuse flowpath, drastically reducing sediment production. Sediment delivery is further reduced because the diffuse flowpath is less likely to allow stream connections."

In plain English, the treatments worked even better than predicted. And, on the other hand, the control roads got significantly worse as a result of the storm.

One of the main things hydrologists try to do with road decommissioning is to disperse concentrated water to prevent road-caused gullies, failures and mass wasting. Decommissioning is also used to reduce "road-stream connectivity." This refers to how roads affect stream hydrology, including sediment delivery, stream chemistry, and aquatic connectivity. In most instances this translates as follows: the higher the road-stream connectivity, the greater the impacts of the road to the aquatic and hydrologic system.

The Mann Creek site experienced an 8-year storm event, just one year after decommissioning was completed. This storm was large enough to justify field researchers to return to collect post-storm data. The table below explains the outcomes.

Table 4: Summary of GRAIP model risk predictions for the Mann Creek road decommissioning project.

Impact/Risk Type	Effect of Treatment: Initial GRAIP Prediction	Effect of Treatment: Post-storm validation
Road-Stream Hydrologic Connectivity	-97%, -2,923 m of connected road	-98%, -2937 m of connected road
Fine Sediment Delivery	-98%, -40.7 Mg/yr	-99%, -41.4 Mg/yr
Landslide Risk	Restored to near natural condition	Restored to near natural condition
Gully Risk	Reduced from low to negligible	Reduced from low to negligible
Stream Crossing Risk		
- plug potential	-100% (eliminated at 13 sites)	-100% (eliminated at 13 sites)
- fill at risk	-100% (807 m^3 removed)	-100% (807 m^3 removed)
- diversion potential	-100% (eliminated at 8 sites)	-100% (eliminated at 8 sites)
Drain Point Problems	-100% (0% vs. 35% of drain points)	+ 12% (0% to 12%)

Impact/Risk Type	Control Roads Effects of Storm	Treatment Roads Effects of Storm
Road-Stream Hydrologic Connectivity	+ 1136 m (+ 12 connected drains)	- 14 m (- 3 connected drains)
Fine Sediment Delivery	+ 38.0 Mg/yr	- 0.5 Mg/yr
Landslides	+ 1 (1,700 Mg)	+ 2 (285 Mg)
Gullies	+ 9 (4.9 Mg)	+ 1 (0.8 Mg)
Drain Point Problems	+ 25% (23% to 48%)	+ 12% (0% to 12%)

Here's an explanation of some of the key data to take from this table. First, almost all of the predicted effects were realized — the treatment reduced road-stream connectivity, radically reduced sediment delivery to the stream system, and reduced the risk of stream crossing failures 100%! The only point where treatment did not function entirely as predicted was with an increase in drain point problems. Some of these problems were caused by a gully that crossed the road, in addition to problems associated with five ephemeral stream crossings that had been treated. The control road, however, experienced far more significant drain point problems, indicating that treatment was still a significant improvement. More significantly, the post-storm validation shows that the road-stream connectivity actually increased as a result of the storm on the control roads as did all of the other impacts, including sediment delivery.

This chart also points out how storms amplify the chronic effects of roads. As the agency continues to struggle to find funding to maintain its road system, the impacts of that system on hydrologic conditions and clean water will only grow.

The data collected from GRAIP analyses on post-storm decommissioning sites clearly shows that road decommissioning, storm proofing and culvert upgrades have the potential to drastically reduce the legacy of road impacts from our forest road system. Legacy Roads and Trails funding provides important dollars for the agency to do just this type of work!

Damage from the April storms. A gullied wheeltrack where flood water was diverted down the road. Photo USDA Forest Service.

Cutslope failure along Mann Creek control road. Photo USDA Forest Service.

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Wildlands CPR wishes to acknowledge the assistance of the Rocky Mountain Research Station in sharing their most recent data. As clear from the many citations, this report is a compilation of the research that the GRAIP team is conducting and would not have been possible without their assistance. In particular, we thank Tom Black and Nathan Nelson for quickly providing data and graphs, including several charts compiling data they are currently analyzing, and for their very helpful assistance with data interpretation as well.

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